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(54) **WHITE BOX TESTING**

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G06F 9/45 (2006.01)
G06F 11/36 (2006.01)

(52) **U.S. Cl.**
CPC ***G06F 11/3684*** (2013.01); ***G06F 11/3676*** (2013.01); ***G06F 11/3688*** (2013.01)

(58) **Field of Classification Search**
CPC G06F 11/3466; G06F 11/3636; G06F 11/3409
USPC 717/133
See application file for complete search history.

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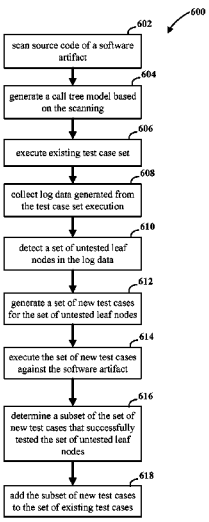
(57) **ABSTRACT**

The source code of a software artifact may be scanned, and a call tree model with leaf nodes may be generated based on the scan. A set of test cases can be executed against the software artifact and log data from the execution can be collected. A set of untested leaf nodes can be detected and a new set of test cases can be generated to test the untested nodes. The new set of test cases are executed and a subset of the test cases which cover the previously untested nodes are added to the existing set of test cases.

1 Claim, 8 Drawing Sheets



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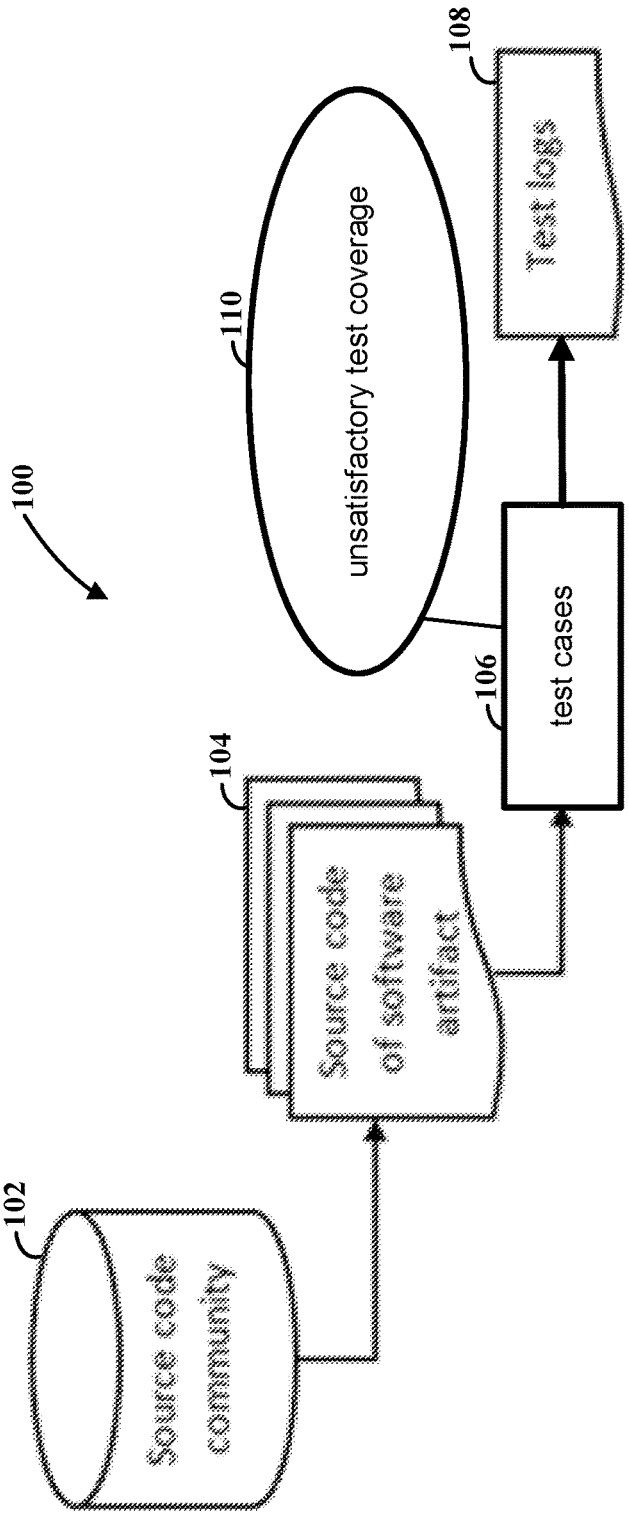
100
102
Source code community
104
Source code of software artifact
106
test cases
108
Test logs
110
unsatisfactory test coverage

FIG. 1

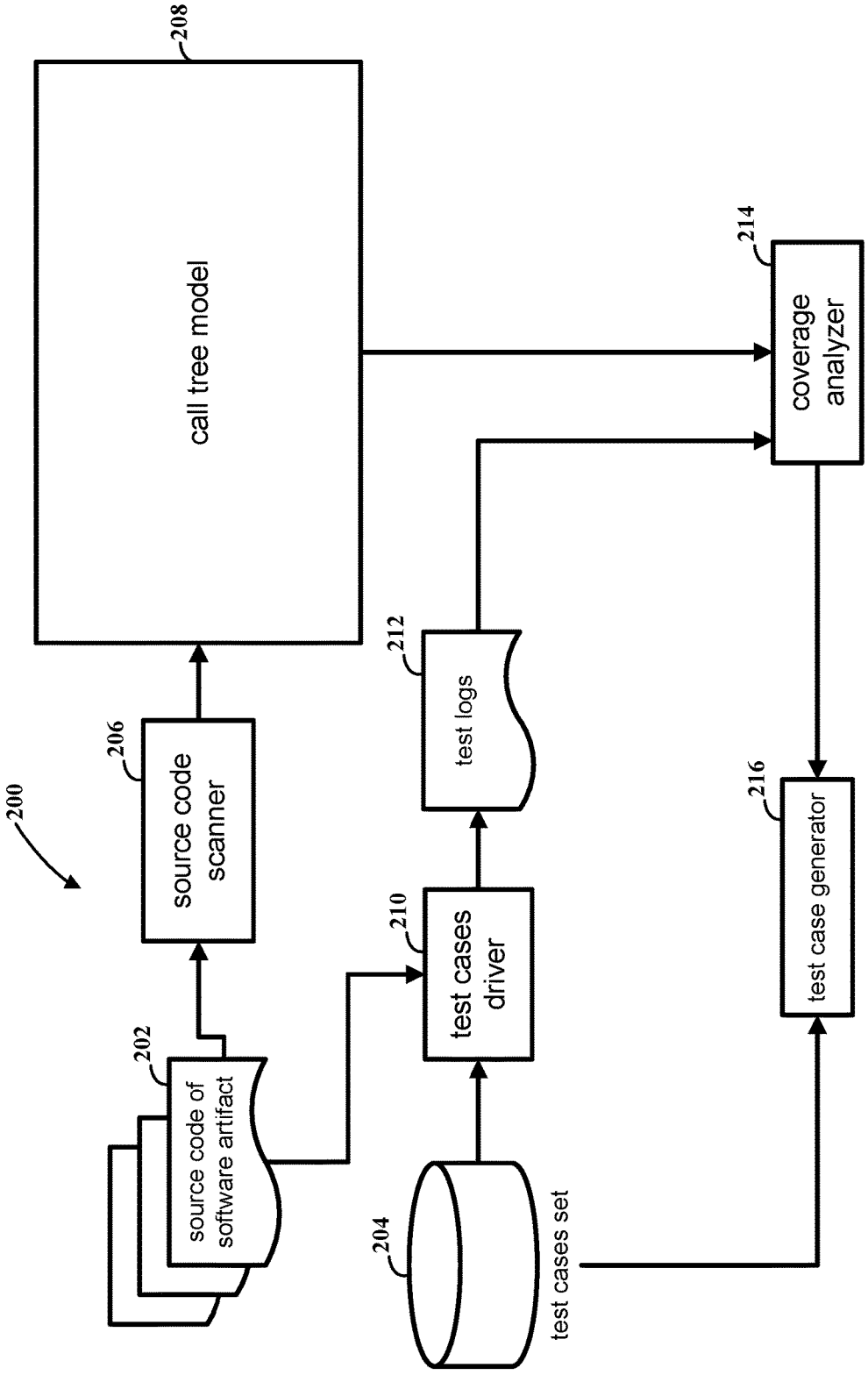
200
208
call tree model
206
source code scanner
202
source code of software artifact
210
test cases driver
212
test logs
204
test cases set
214
coverage analyzer
216
test case generator

FIG. 2

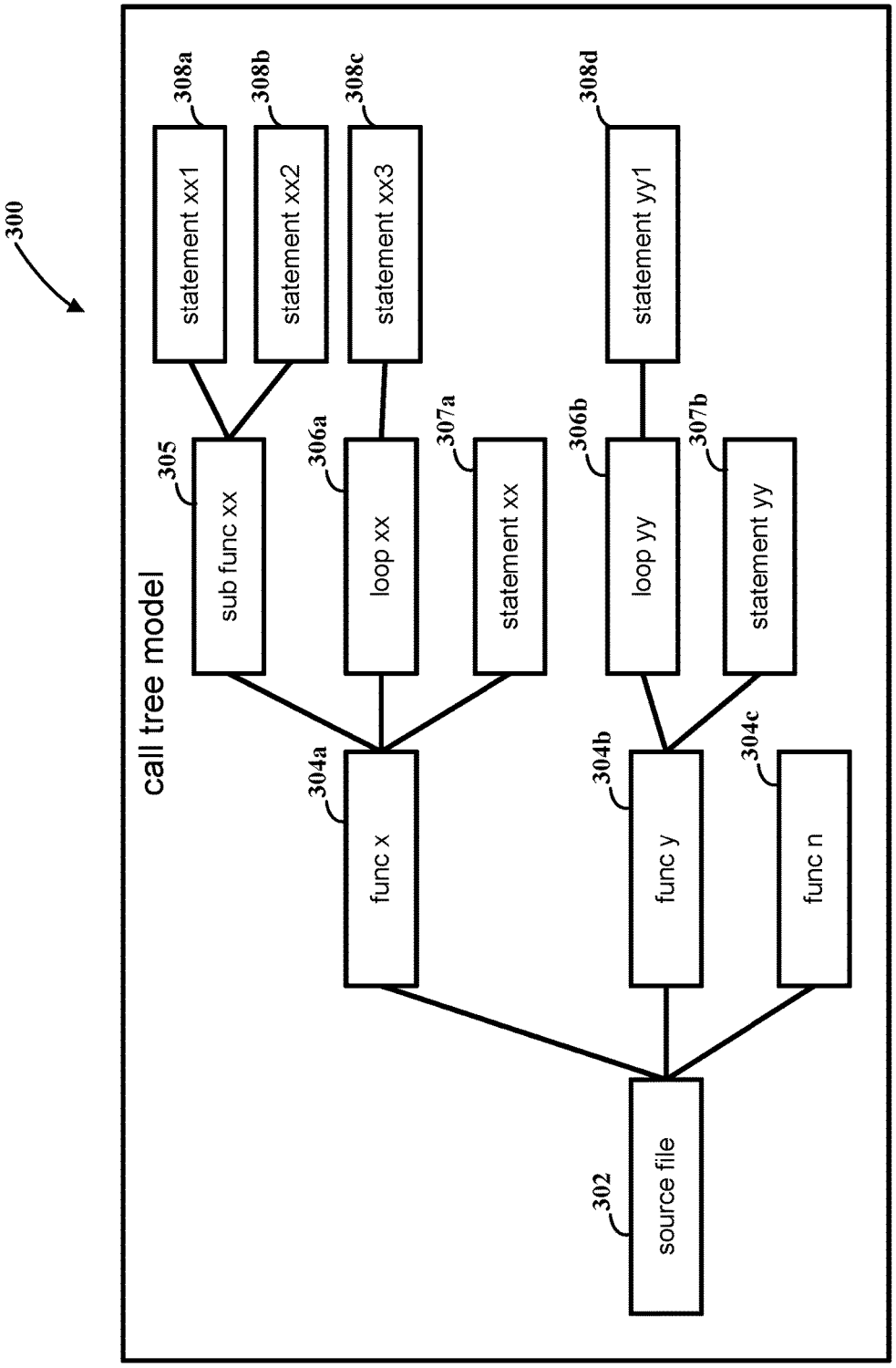
300
call tree model
source file
302
func x
304a
func y
304b
func n
304c
sub func xx
305
loop xx
306a
loop yy
306b
statement xx
307a
statement yy
307b
statement xx1
308a
statement xx2
308b
statement xx3
308c
statement yy1
308d

FIG. 3

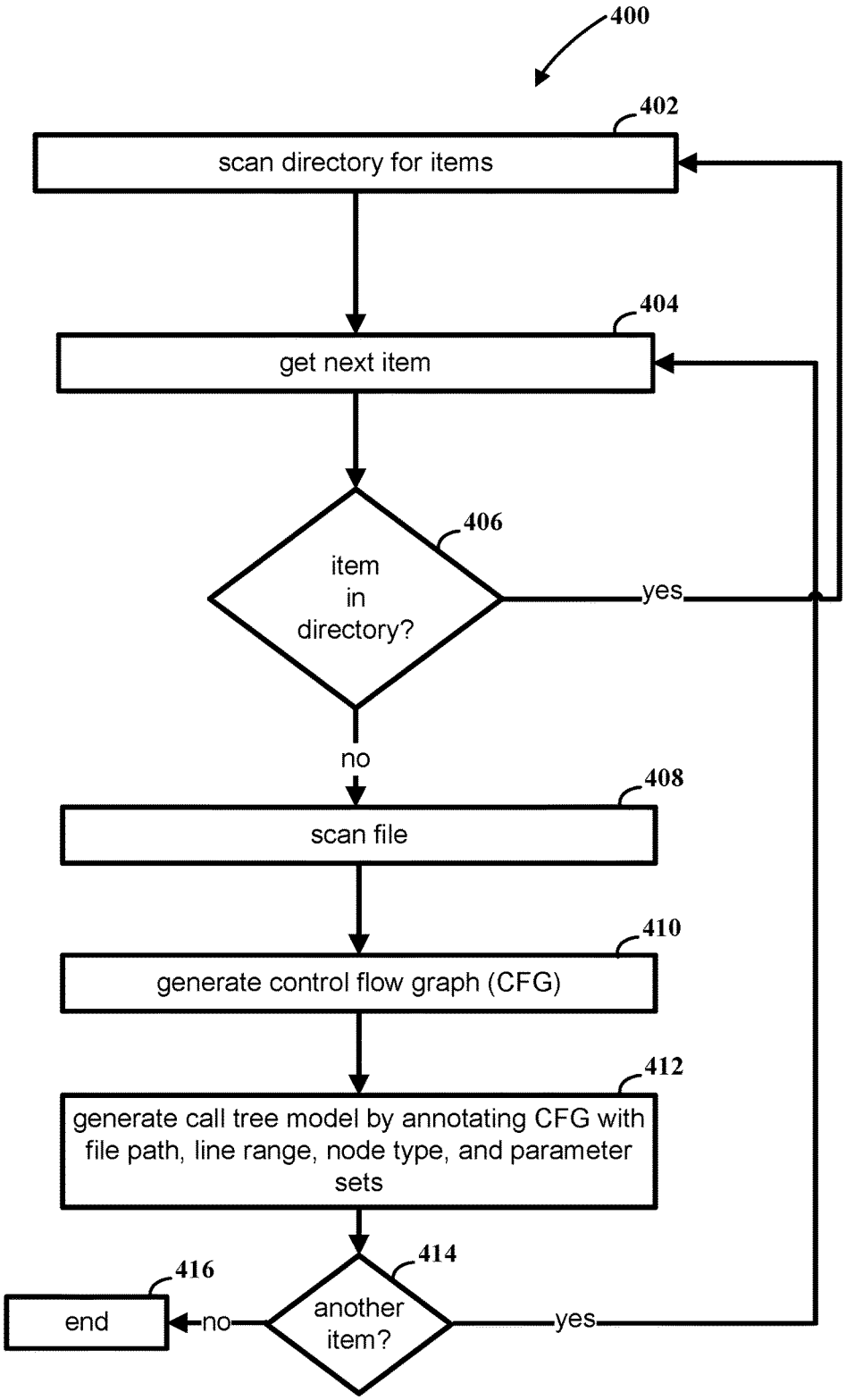
400
402
scan directory for items
404
get next item
406
item in directory?
yes
no
408
scan file
410
generate control flow graph (CFG)
412
generate call tree model by annotating CFG with file path, line range, node type, and parameter sets
414
another item?
yes
no
416
end

FIG. 4

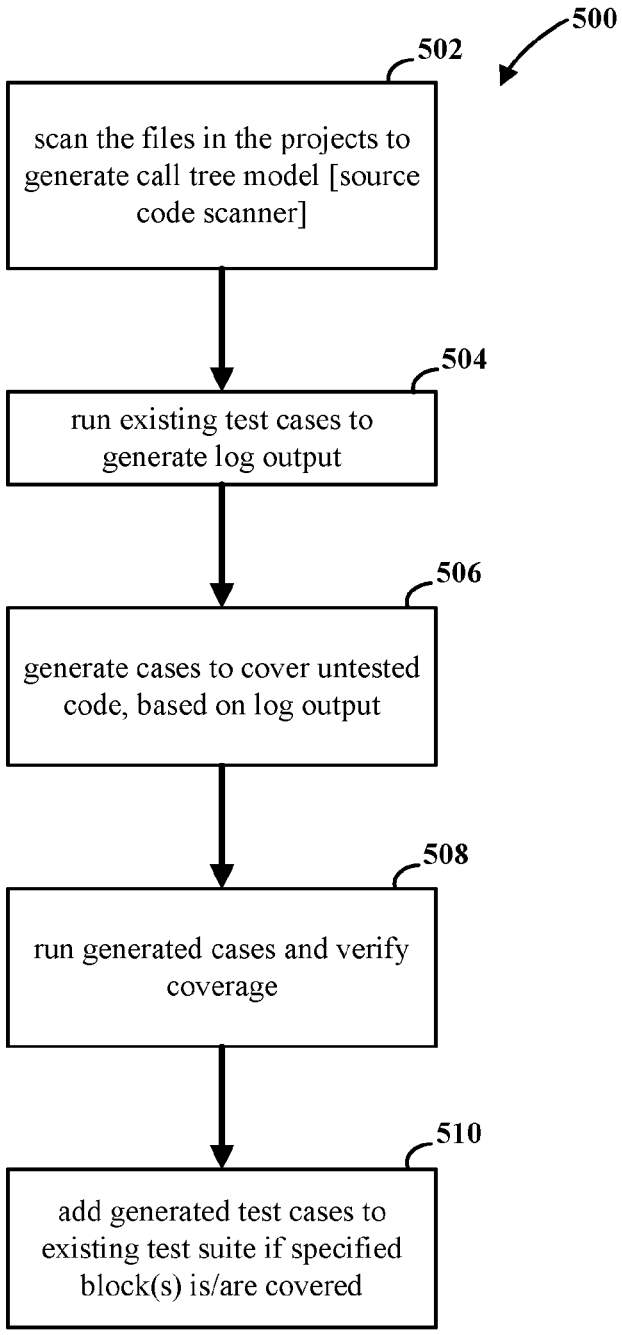
500
502
scan the files in the projects to generate call tree model [source code scanner]
504
run existing test cases to generate log output
506
generate cases to cover untested code, based on log output
508
run generated cases and verify coverage
510
add generated test cases to existing test suite if specified block(s) is/are covered

FIG. 5

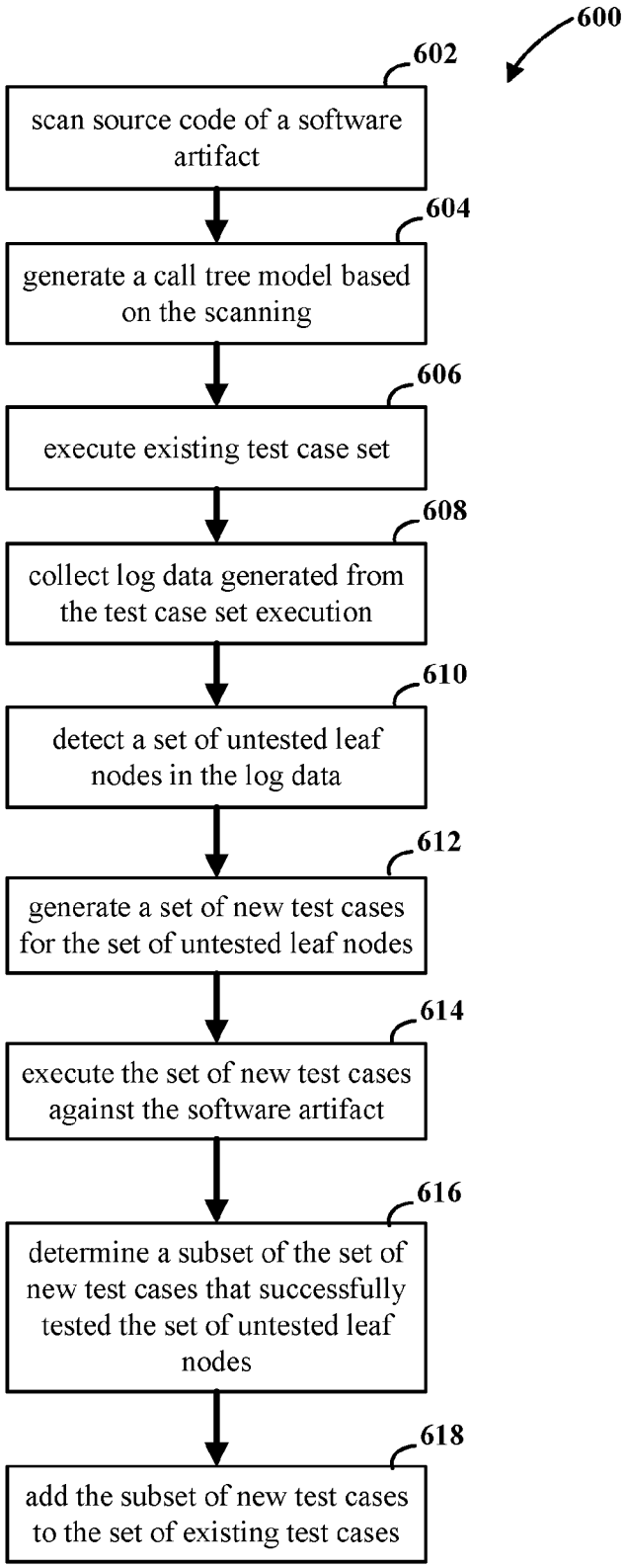
600
602
scan source code of a software artifact
604
generate a call tree model based on the scanning
606
execute existing test case set
608
collect log data generated from the test case set execution
610
detect a set of untested leaf nodes in the log data
612
generate a set of new test cases for the set of untested leaf nodes
614
execute the set of new test cases against the software artifact
616
determine a subset of the set of new test cases that successfully tested the set of untested leaf nodes
618
add the subset of new test cases to the set of existing test cases

FIG. 6

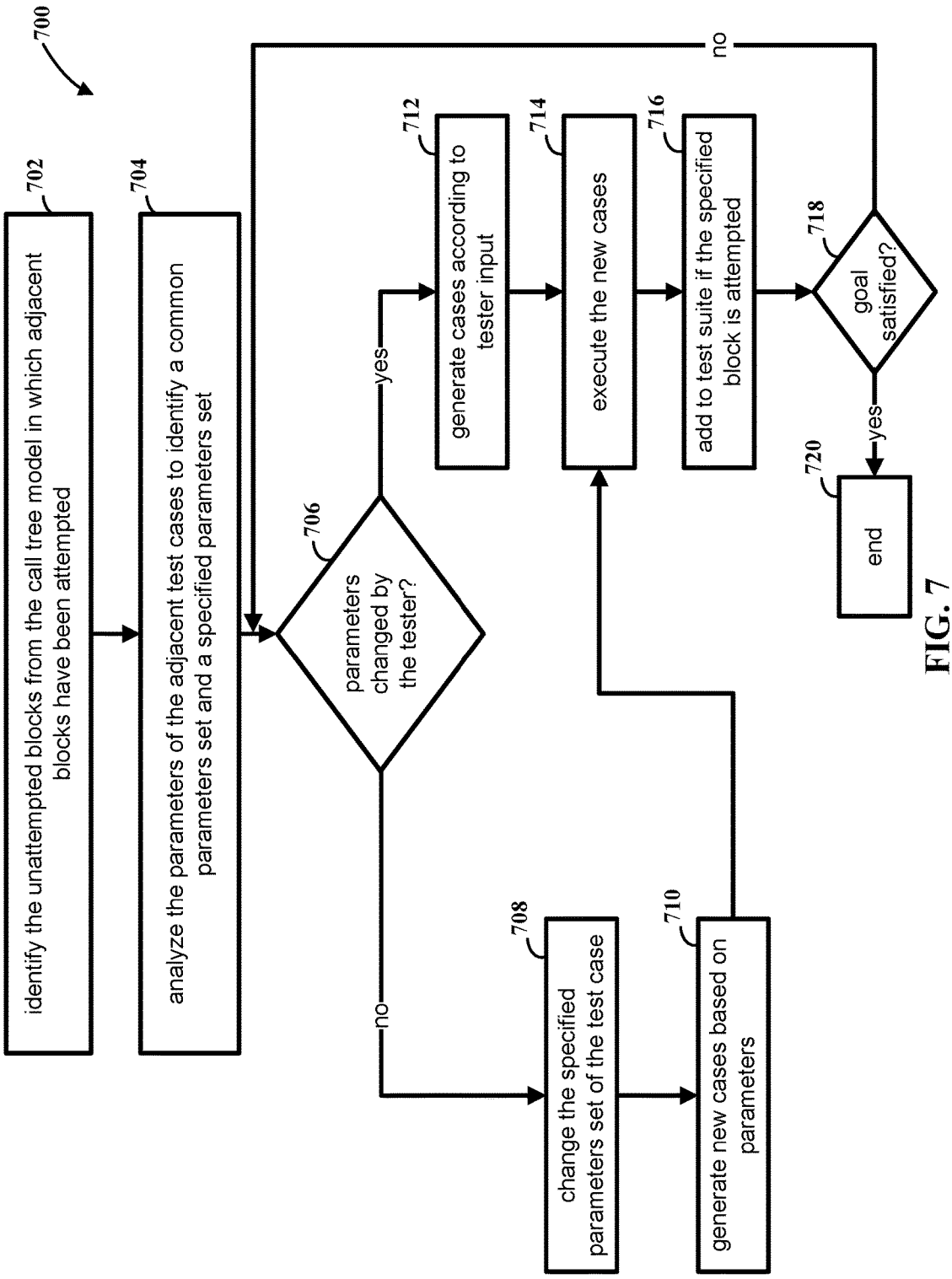
700
identify the unattempted blocks from the call tree model in which adjacent blocks have been attempted
702
analyze the parameters of the adjacent test cases to identify a common parameters set and a specified parameters set
704
parameters changed by the tester?
706
yes
no
generate cases according to tester input
712
execute the new cases
714
add to test suite if the specified block is attempted
716
goal satisfied?
718
no
yes
end
720
change the specified parameters set of the test case
708
generate new cases based on parameters
710

FIG. 7

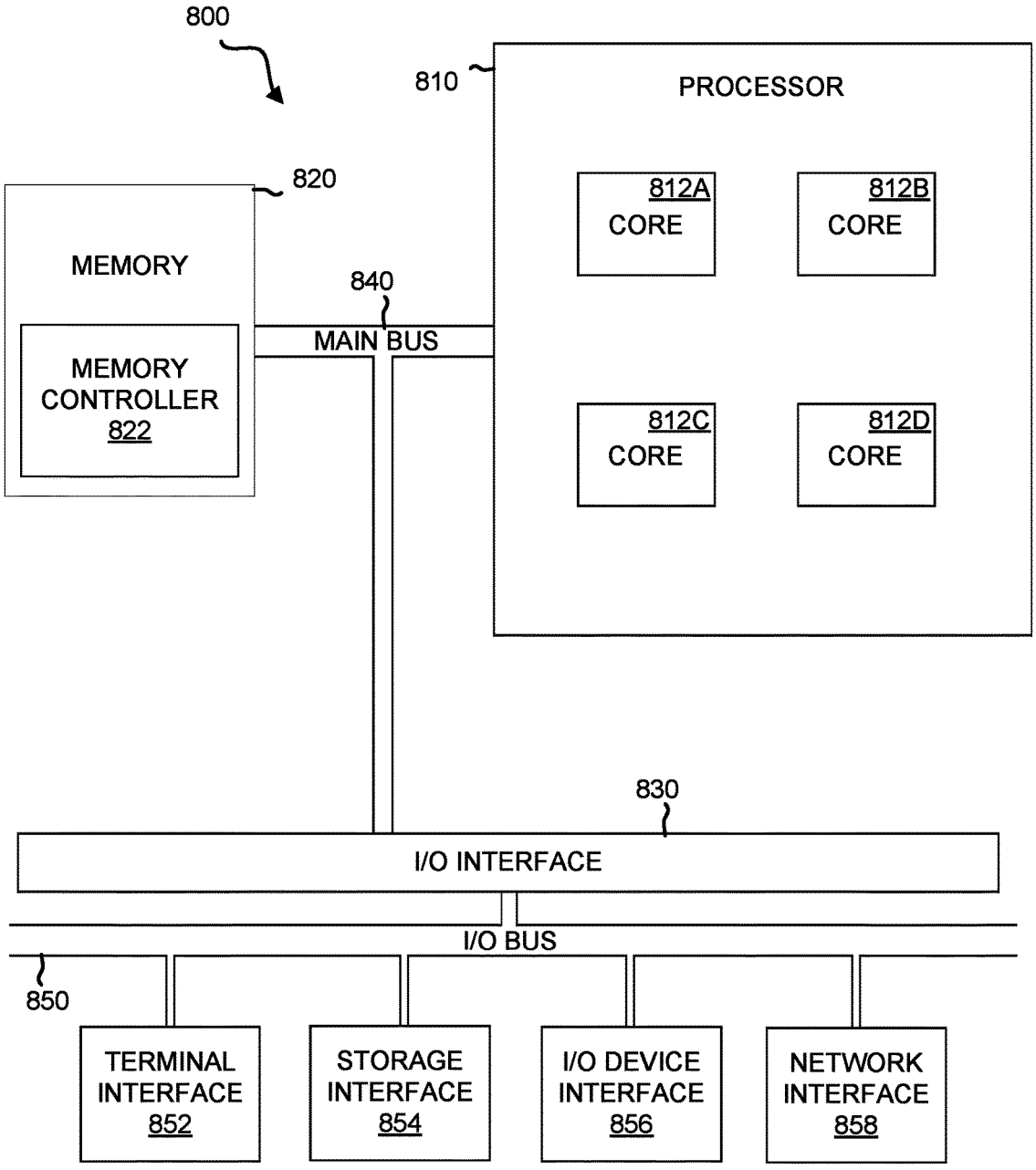
800
810
PROCESSOR
812A
CORE
812B
CORE
812C
CORE
812D
CORE
820
MEMORY
MEMORY
CONTROLLER
822
840
MAIN BUS
830
I/O INTERFACE
I/O BUS
850
TERMINAL
INTERFACE
852
STORAGE
INTERFACE
854
I/O DEVICE
INTERFACE
856
NETWORK
INTERFACE
858

FIG. 8

WHITE BOX TESTING

BACKGROUND

The present disclosure relates to white box testing, and more specifically, to test case generation in white box testing.

White box testing is a method of software testing that may test the internal structure and workings of an application. As opposed to black box testing, which may test the functionality of software, white box testing provides for an internal perspective of the system. In white box testing, this internal perspective may be used by a tester to design test cases to run and test various paths within the execution of the software code. The output of these test cases may be compared with the designed or intended outputs.

White box testing may be applied at the unit level. However, it may also be used at integration level, for example, by testing pathways between units during integration. White box testing may also be used at the system level, to test paths between subsystems during system-level testing.

SUMMARY

Embodiments of the present disclosure may be directed toward a method that begins when the source code of a software artifact is scanned. A call tree model may be generated based on the scan. The call tree model may have a set of leaf nodes, where each leaf node represents a source code statement. A set of existing test cases may be executed against the software artifact, and log data, generated from the executing, may be collected. A set of untested leaf nodes in the log data may be detected, and a set of new test cases may be generated for the set of untested leaf nodes. Each new test case may be generated to test untested leaf nodes in the set. The set of new test cases may be executed against the software artifact, and a subset of the new test cases, where the subset contains cases that successfully tested one or more of the untested leaf nodes, may be determined. The subset of new test cases may then be added to the set of existing test cases.

Embodiments of the present disclosure may be directed toward a system with a computer readable storage medium with program instructions stored thereon and a processor configured to execute the program instructions to perform a method. The method may begin when the source code of a software artifact is scanned. A call tree model may be generated based on the scan. The call tree model may have a set of leaf nodes, where each leaf node represents a source code statement. A set of existing test cases may be executed against the software artifact, and log data, generated from the executing, may be collected. A set of untested leaf nodes in the log data may be detected, and a set of new test cases may be generated for the set of untested leaf nodes. Each new test case may be generated to test untested leaf nodes in the set. The set of new test cases may be executed against the software artifact, and a subset of the new test cases, where the subset contains cases that successfully tested one or more of the untested leaf nodes, may be determined. The subset of new test cases may then be added to the set of existing test cases.

Embodiments of the present disclosure may be directed toward a computer program product with a computer readable storage medium with program instructions. The computer readable storage medium is not a transitory signal per se. The program instructions may be executable by a computer processing circuit to cause the circuit to perform a method. The method may begin when the source code of a software artifact is scanned. A call tree model may be generated based on the scan. The call tree model may have a set of leaf nodes, where each leaf node represents a source code statement. A set of existing test cases may be executed against the software artifact, and log data, generated from the executing, may be collected. A set of untested leaf nodes in the log data may be detected, and a set of new test cases may be generated for the set of untested leaf nodes. Each new test case may be generated to test untested leaf nodes in the set. The set of new test cases may be executed against the software artifact, and a subset of the new test cases, where the subset contains cases that successfully tested one or more of the untested leaf nodes, may be determined. The subset of new test cases may then be added to the set of existing test cases.

The above summary is not intended to describe each illustrated embodiment or every implementation of the present disclosure.

BRIEF DESCRIPTION OF THE DRAWINGS

The drawings included in the present application are incorporated into, and form part of, the specification. They illustrate embodiments of the present disclosure and, along with the description, serve to explain the principles of the disclosure. The drawings are only illustrative of certain embodiments and do not limit the disclosure.

FIG. **1** depicts an overview of a white box testing flow, highlighting the gap in test cases, according to embodiments.

FIG. **2** depicts a block diagram of an overview of a system flow for generating test cases, using a call tree model, according to embodiments.

FIG. **3** depicts a block diagram of a call tree model for mapping execution paths of a software artifact, according to embodiments.

FIG. **4** depicts a flow chart of a method for the generation of the call tree model from a root directory, according to embodiments.

FIG. **5** depicts a flow chart of a method for generating test cases based on a call tree model, consistent with embodiments.

FIG. **6** depicts a flow chart of a method for generating a set of new test cases to cover gaps in the white box testing of a software artifact, according to embodiments.

FIG. **7** depicts a flow chart of a method for generating a set of test cases, based on unattempted blocks or nodes on a call tree model, according to embodiments.

FIG. **8** depicts a block diagram of an example computer system, according to embodiments.

While the invention is amenable to various modifications and alternative forms, specifics thereof have been shown by way of example in the drawings and will be described in detail. It should be understood, however, that the intention is not to limit the invention to the particular embodiments described. On the contrary, the intention is to cover all modifications, equivalents, and alternatives falling within the spirit and scope of the invention.

DETAILED DESCRIPTION

Aspects of the present disclosure relate to white box testing; more particular aspects relate to test case generation in white box testing. While the present disclosure is not necessarily limited to such applications, various aspects of

the disclosure may be appreciated through a discussion of various examples using this context.

White box testing may be used in software development to test code for a particular application. Before an application (or a component of an application) is released for use, all of the application's code statements may be tested. Open source development and increased collaborations among developers have led to very large codes as well as a large number of source code files. The increased size of the files, as well as the increase in collaborations, may result in a developer using code which is unfamiliar. Identifying and creating test cases for applications in this context may be difficult.

White box testing may involve tracing possible execution paths through the code and working out which input values would force the execution of these paths. The source code of a software application may be tested by scanning the source code of the software artifact. Based on the scanning, a system may generate a call tree model. This call tree model may serve as a visualization of the coverage of the logical branches of the source code, and the call tree model may have different nodes that reflect the different paths and sequence of the execution of the source code.

The software artifact may have a set of existing test cases for which the output is known. After the call tree model is generated, the system may then execute the set of existing test cases against the software artifact. Output (e.g., log data) may be generated from the test case execution, and this data may be collected by the system. Using this data, the system may detect a set of untested leaf nodes on the call tree. These untested leaf nodes indicate paths or sequences in the source code that are not currently covered by the set of test cases (e.g., gaps in the test cases). A set of additional test cases can then be generated for the untested (e.g., unattempted) nodes in the call tree. These additional test cases can then be run against the software artifact and the additional test cases which did, in fact, test the previously untested nodes can be determined and added to the set of existing test cases. Thus, the set of test cases can be updated to fill in gaps in the test case coverage and to more comprehensively cover the code.

FIG. **1** depicts an overview of a white box testing flow **100**, highlighting the gap in test cases, according to embodiments. The testing flow **100** depicts source code community **102** as a database. This may represent a set of data storage locations at which source code may be stored. For example, this may be source code exchanged in an open source community. It could also be source code purchased or accessed from a third-party developer over the Internet, or any location that source code may be stored in the broader source code community.

The source code community may generate or identify source code from software artifacts **104**. Each source code artifact may be received with a set of test cases **106**. These test cases **106** may have been developed along with the original source code in the software artifact **104**. However, as noted at comment **110**, the test cases **106** which were supplied with the software artifacts **104** may provide unsatisfactory test coverage, per comment **110**. Test coverage may be unsatisfactory due to gaps in the test coverage, in which each pathway in the execution of the source code of the software artifact **104** is not covered (i.e., tested). The test cases **106** may generate one or more test logs **108** (i.e., output), when they are run against the source code of the particular software artifact. These test logs **108** can be compared with the predicted output of the test cases to determine correctness of the source code.

FIG. **2** depicts a block diagram of an overview of a system flow **200** for generating test cases, using a call tree model, according to embodiments. The source code from a particular software artifact **202** may be accessed by a source code scanner **206**. The source code scanner may scan the source code files **202** in order to generate a call tree model **208**. A call tree model like the call tree model **208** is discussed in detail at FIG. **3**. The call tree model **208** can depict each of the logical paths of the source code artifact.

In embodiments, the test cases driver **210** is built out from the source code of the software artifact **202**. The test cases driver **210** may access and run a set of test cases **204**. The set of test cases **204** may have been developed alongside the source code **202**. The test cases set **204** may also be a set of cases developed prior to the source code (e.g., by the source code developers), after the source code was written (e.g., by the original source code developers, by an automated process, or by a third-party following, for example, modifications to the source code), or in a combination of the above. The test cases set **204** can be run by the test cases driver **210** to create (i.e., output) the test logs **212**. Test logs, in a white box testing environment, may include a set of log entries that contain information on each of the executed paths.

In embodiments, the coverage analyzer **214** may then access both the test logs **212** and the call tree model **208**. The coverage analyzer **214** may analyze the various nodes of the call tree model **208** to determine which nodes have been attempted, which have been unattempted, and which nodes were partially (but not fully) attempted. The coverage analyzer **214** may then color code the nodes of the call tree model **208** according to the determination. For example, a node on the call tree model **208** that was fully attempted may be colored black. A node which was unattempted may be colored white, and a node which was only partially attempted may be colored grey by the coverage analyzer **214**. For nodes in the call tree model **208** that were unattempted, the coverage analyzer **214** may analyze the nodes, and locate nodes which were uncovered by the previous testing. The coverage analyzer **214** may link the located uncovered nodes together to generate a list or blocks of uncovered code. The coverage analyzer may also determine which test cases provide good coverage of adjacent neighbor nodes.

The test case generator **216** may use the uncovered code data from the coverage analyzer **214**, to provide a list of uncovered code blocks to a user (e.g., a software tester). The test case generator **216** may provide this data to a user to help guide the tester to design new test cases to file the gaps in testing. The test case generator **216** may also generate test cases without user intervention, based on the data received from the coverage analyzer **214**. For example, for an "if" block, where one of the "if" statements and one of the "else" statements is covered, the test case generate **216** may analyze the code and adjust the input parameter to cover the other statement. This can be done using a case or set of cases which covers the "if" or "else" statement at issue, as a model. A new test case for a "select" block may be generated by the test case generator **216** in a similar manner as for the "if" block. The new test cases may then be run, and those cases which are determined to, in fact, cover previously untested (i.e., uncovered) blocks may be added to the test cases set **204**.

FIG. **3** depicts a block diagram of a call tree model **300** for mapping execution paths of a software artifact, according to embodiments. As depicted herein, the source code may be contained within a source file **302**. The call tree model may depict a number of functions (for example, **304** func x, y, and

z, and sub func xx **305**), loops (for example, loop xx and loop yy **306**), and statements (for example, statements xx and yy **307**, and statements xx1, xx2, xx3, and yy1 **308**). In the call tree model **300**, statements may be represented as leaf nodes, while loop or function calls may be represented as non-leaf nodes. In embodiments, a set of intermediate nodes may be included in the call tree model **300**, and may represent non-leaf nodes that are branch, loop, or function call nodes.

In embodiments, the generation of the call tree model may also include the generation of various data related to each of the nodes in the call tree model, as well as other execution data about the source code. For example, each node representation in the call tree model may include the following: a node name, a node type, a conditional or parameter or set of parameters, line range, parent ptr, child list, an indication of whether or not the node has been tested (i.e., "isTested"), and a cases list. The node type could be, for example, a file, a function, a branch, a selected, or a loop. The line range may include a node range start line number and a node range end line number. The parent ptr may be data that points to the particular node's parent node. The child list may include data that contains all the child nodes for the particular node. In some instances, the order of the child nodes in the list may indicate the order the child nodes exist in the code block.

FIG. **4** depicts a flow chart of a method **400** for the generation of the call tree model from a root directory, according to embodiments. The call tree model may be generated starting from a root directory (i.e., a root node). The source code scanner, for example, the source code scanner **206** in FIG. **2**, may begin to do a directory scan for an item in the root directory, per **402**. For example, the item could be a directory, sub-directory, or files under the sub-directory. The source code scanner could locate and get the (next) item, per **404**. If the item is in the directory, meaning for example, it has been scanned previously, at **406**, the source code scanner can return to scanning, per **402**. If the item is not in the directory, at **406**, the source code scanner can scan the file, per **408**. Using the data from the file scan, the source code scanner can generate a control flow graph (CFG) for the file, per **410**, where the CFG can depict all the paths that could be traversed during the execution of the file. At **412**, the call tree model can then be generated by the annotation of the CFG. The annotations can include things like file path, line range, node type, and sets of parameters specifying particular nodes. If another item, at **414**, is available in the directory, the source code scanner can return to **404**, to get the next item and continue through the flow. If all items in the directory have been accounted for, at **414**, the source code scanner can end, per **416**.

FIG. **5** depicts a flow chart of a method **500** for generating test cases based on a call tree model, consistent with embodiments. At **502**, the method may begin when the system scans the files in the projects to generate a call tree model. For example, the call tree model can be generated as described in method **400** of FIG. **4**. As described herein, the call tree model may be generated by a source code scanner, for example the source code scanner **206** of FIG. **2**. The system may then run existing test cases to generate output, for example log output, per **504**. In embodiments, the test cases can be from a test case set, for example, test cases set **204** of FIG. **2**. The test case driver **210** may execute the test cases to generate the test logs **212**, both of FIG. **2**. The system may then generate cases to cover the untested code, based on, for example, the log output, per **506**. The system may then run the generated cases and verify the coverage, per **508**. Based on the output generated from running the newly generated cases, the system may add the generated test cases to the existing test suite if the specified (e.g., the previously uncovered test cases), are covered, per **510**. For example, the newly generated test cases that cover the specified cases may be added to the test case set **204** of FIG. **2**.

FIG. **6** depicts a flow diagram of a method **600** for generating a set of new test cases to cover gaps in the white box testing of a software artifact, according to embodiments. The system may scan the source code of a software artifact, per **602**. The system may then generate a call tree model based on the scanning, per **604**. The model may be generated according to, for example, the method **400** described in FIG. **4**. The system may then execute the existing test case set, as described herein, per **606**, and collect the log data which is generated from the test case set execution, per **608**. The system may detect a set of untested leaf nodes in the log data, per **610**. For example, these untested nodes could be detected by a coverage analyzer **214**, as in FIG. **2**. The system may generate a set of new test cases for the set of untested leaf nodes, per **612**. The new test cases may be generated as described in, for example, method **700** of FIG. **7**, or in another way. The system may then execute the set of new test cases against the software artifact, per **614**. Based on the log output of the execution, the system may determine a subset of the newly generated test cases that successfully tests the set of previously untested leaf nodes, per **616**. In embodiments, this determining may be done by a test case generator, for example, test case generator **216** of FIG. **2**. The system can then add the subset of new test cases to the set of the existing test cases, per **618**.

FIG. **7** depicts a flow chart of a method **700** for generating a set of test cases, based on unattempted blocks or nodes on a call tree model, according to embodiments. The method **700** may begin when the system, for example, the coverage analyzer **214** of FIG. **2**, identifies the unattempted blocks from the call tree model, per **702**. In embodiments, the coverage analyzer may detect which blocks in the call tree model have not been attempted, but are adjacent to blocks that have been attempted. The system may then analyze the parameters of the adjacent test cases to identify a common parameter set and a set of specified parameters, per **704**. The system may then determine whether or not the parameters have been changed (e.g., manually) by the tester, for example, in response to the generated call tree model indicating gaps in the testing coverage, per **706**.

According to embodiments, if the parameters are not adjusted by the tester, based on the identified gaps in the test set, the system may change a set of specified parameters for the test case, per **708**. Based on the new parameters, the system may generate a set of new test cases, the new test cases being intended to cover the previously uncovered blocks (i.e., nodes) on the call tree model. The system may execute the new cases, per **714**, and add the newly generated test cases to the test suite (i.e., set of test cases), if the specified, previously unattempted blocks are attempted, per **716**.

If, at **706**, the system detects that the parameters have been changed by the tester, the system may generate cases, according to the test input (e.g., responsive to the new manually input parameters), per **712**. The system may then execute the new cases against the original source code, per **714**, and add a subset of the new test cases to the test suite (i.e., set of test cases), if the new test cases covered the unattempted (i.e., specified) cases, per **716**.

In embodiments, once the new test cases have been added, as appropriate, per **716**, the system may determine if the goal

has been satisfied, per **718**. For example, the goal may be a coverage goal of how many nodes or a percentage of nodes on a call tree model are covered by test cases, or another goal. If at **718**, the system determines that the goal has been satisfied, the flow may end, per **720**. If, at **718**, the system determines the goal has not been satisfied, the system may return to **706**, to detect tester-initiated changes in the specified parameters, and continue through the flow of test case generation, until the coverage goal has been satisfied.

FIG. **8** depicts the representative major components of an example computer system **800** that may be used, in accordance with embodiments of the present disclosure. It is appreciated that individual components may vary in complexity, number, type, and\or configuration. The particular examples disclosed are for example purposes only and are not necessarily the only such variations. The computer system **800** may comprise a processor **810**, memory **820**, an input/output interface (herein I/O or I/O interface) **830**, and a main bus **840**. The main bus **840** may provide communication pathways for the other components of the computer system **800**. In some embodiments, the main bus **840** may connect to other components such as a specialized digital signal processor (not depicted).

The processor **810** of the computer system **800** may be comprised of one or more cores **812**A, **812**B, **812**C, **812**D (collectively **812**). The processor **810** may additionally include one or more memory buffers or caches (not depicted) that provide temporary storage of instructions and data for the cores **812**. The cores **812** may perform instructions on input provided from the caches or from the memory **820** and output the result to caches or the memory. The cores **812** may be comprised of one or more circuits configured to perform one or methods consistent with embodiments of the present disclosure. In some embodiments, the computer system **800** may contain multiple processors **810**. In some embodiments, the computer system **800** may be a single processor **810** with a singular core **812**.

The memory **820** of the computer system **801** may include a memory controller **822**. In some embodiments, the memory **820** may comprise a random-access semiconductor memory, storage device, or storage medium (either volatile or non-volatile) for storing data and programs. In some embodiments, the memory may be in the form of modules (e.g., dual in-line memory modules). The memory controller **822** may communicate with the processor **810**, facilitating storage and retrieval of information in the memory **820**. The memory controller **822** may communicate with the I/O interface **830**, facilitating storage and retrieval of input or output in the memory **820**.

The I/O interface **830** may comprise an I/O bus **850**, a terminal interface **852**, a storage interface **854**, an I/O device interface **856**, and a network interface **858**. The I/O interface **830** may connect the main bus **840** to the I/O bus **850**. The I/O interface **830** may direct instructions and data from the processor **810** and memory **820** to the various interfaces of the I/O bus **850**. The I/O interface **830** may also direct instructions and data from the various interfaces of the I/O bus **850** to the processor **810** and memory **820**. The various interfaces may include the terminal interface **852**, the storage interface **854**, the I/O device interface **856**, and the network interface **858**. In some embodiments, the various interfaces may include a subset of the aforementioned interfaces (e.g., an embedded computer system in an industrial application may not include the terminal interface **852** and the storage interface **854**).

Logic modules throughout the computer system **800**—including but not limited to the memory **820**, the processor **810**, and the I/O interface **830**—may communicate failures and changes to one or more components to a hypervisor or operating system (not depicted). The hypervisor or the operating system may allocate the various resources available in the computer system **800** and track the location of data in memory **820** and of processes assigned to various cores **812**. In embodiments that combine or rearrange elements, aspects and capabilities of the logic modules may be combined or redistributed. These variations would be apparent to one skilled in the art.

The present invention may be a system, a method, and/or a computer program product. The computer program product may include a computer readable storage medium (or media) having computer readable program instructions thereon for causing a processor to carry out aspects of the present invention.

The computer readable storage medium can be a tangible device that can retain and store instructions for use by an instruction execution device. The computer readable storage medium may be, for example, but is not limited to, an electronic storage device, a magnetic storage device, an optical storage device, an electromagnetic storage device, a semiconductor storage device, or any suitable combination of the foregoing. A non-exhaustive list of more specific examples of the computer readable storage medium includes the following: a portable computer diskette, a hard disk, a random access memory (RAM), a read-only memory (ROM), an erasable programmable read-only memory (EPROM or Flash memory), a static random access memory (SRAM), a portable compact disc read-only memory (CD-ROM), a digital versatile disk (DVD), a memory stick, a floppy disk, a mechanically encoded device such as punch-cards or raised structures in a groove having instructions recorded thereon, and any suitable combination of the foregoing. A computer readable storage medium, as used herein, is not to be construed as being transitory signals per se, such as radio waves or other freely propagating electromagnetic waves, electromagnetic waves propagating through a waveguide or other transmission media (e.g., light pulses passing through a fiber-optic cable), or electrical signals transmitted through a wire.

Computer readable program instructions described herein can be downloaded to respective computing/processing devices from a computer readable storage medium or to an external computer or external storage device via a network, for example, the Internet, a local area network, a wide area network and/or a wireless network. The network may comprise copper transmission cables, optical transmission fibers, wireless transmission, routers, firewalls, switches, gateway computers and/or edge servers. A network adapter card or network interface in each computing/processing device receives computer readable program instructions from the network and forwards the computer readable program instructions for storage in a computer readable storage medium within the respective computing/processing device.

Computer readable program instructions for carrying out operations of the present invention may be assembler instructions, instruction-set-architecture (ISA) instructions, machine instructions, machine dependent instructions, microcode, firmware instructions, state-setting data, or either source code or object code written in any combination of one or more programming languages, including an object oriented programming language such as Smalltalk, C++ or the like, and conventional procedural programming languages, such as the "C" programming language or similar programming languages. The computer readable program instructions may execute entirely on the user's computer,

partly on the user's computer, as a stand-alone software package, partly on the user's computer and partly on a remote computer or entirely on the remote computer or server. In the latter scenario, the remote computer may be connected to the user's computer through any type of network, including a local area network (LAN) or a wide area network (WAN), or the connection may be made to an external computer (for example, through the Internet using an Internet Service Provider). In some embodiments, electronic circuitry including, for example, programmable logic circuitry, field-programmable gate arrays (FPGA), or programmable logic arrays (PLA) may execute the computer readable program instructions by utilizing state information of the computer readable program instructions to personalize the electronic circuitry, in order to perform aspects of the present invention.

Aspects of the present invention are described herein with reference to flowchart illustrations and/or block diagrams of methods, apparatus (systems), and computer program products according to embodiments of the invention. It will be understood that each block of the flowchart illustrations and/or block diagrams, and combinations of blocks in the flowchart illustrations and/or block diagrams, can be implemented by computer readable program instructions.

These computer readable program instructions may be provided to a processor of a general purpose computer, special purpose computer, or other programmable data processing apparatus to produce a machine, such that the instructions, which execute via the processor of the computer or other programmable data processing apparatus, create means for implementing the functions/acts specified in the flowchart and/or block diagram block or blocks. These computer readable program instructions may also be stored in a computer readable storage medium that can direct a computer, a programmable data processing apparatus, and/or other devices to function in a particular manner, such that the computer readable storage medium having instructions stored therein comprises an article of manufacture including instructions which implement aspects of the function/act specified in the flowchart and/or block diagram block or blocks.

The computer readable program instructions may also be loaded onto a computer, other programmable data processing apparatus, or other device to cause a series of operational steps to be performed on the computer, other programmable apparatus or other device to produce a computer implemented process, such that the instructions which execute on the computer, other programmable apparatus, or other device implement the functions/acts specified in the flowchart and/or block diagram block or blocks.

The flowchart and block diagrams in the Figures illustrate the architecture, functionality, and operation of possible implementations of systems, methods, and computer program products according to various embodiments of the present invention. In this regard, each block in the flowchart or block diagrams may represent a module, segment, or portion of instructions, which comprises one or more executable instructions for implementing the specified logical function(s). In some alternative implementations, the functions noted in the block may occur out of the order noted in the figures. For example, two blocks shown in succession may, in fact, be executed substantially concurrently, or the blocks may sometimes be executed in the reverse order, depending upon the functionality involved. It will also be noted that each block of the block diagrams and/or flowchart illustration, and combinations of blocks in the block diagrams and/or flowchart illustration, can be implemented by special purpose hardware-based systems that perform the specified functions or acts or carry out combinations of special purpose hardware and computer instructions.

It is understood in advance that although this disclosure includes a detailed description on cloud computing, implementation of the teachings recited herein are not limited to a cloud computing environment. Rather, embodiments of the present invention are capable of being implemented in conjunction with any other type of computing environment now known or later developed.

The descriptions of the various embodiments of the present disclosure have been presented for purposes of illustration, but are not intended to be exhaustive or limited to the embodiments disclosed. Many modifications and variations will be apparent to those of ordinary skill in the art without departing from the scope and spirit of the described embodiments. The terminology used herein was chosen to explain the principles of the embodiments, the practical application or technical improvement over technologies found in the marketplace, or to enable others of ordinary skill in the art to understand the embodiments disclosed herein.

What is claimed is:

1. A method comprising:

scanning source code of a software artifact, the scanning starting at a root directory;

generating, based on the scanning, a call tree model, the call tree model comprising a set of leaf nodes, wherein each leaf node represents a source code statement, and a set of intermediate nodes, wherein the set of intermediate nodes represent one of a group consisting of a branch, a loop, and a function call;

generating, in response to the scanning, a set of execution data about the source code, the set of execution data comprising a node name, a node type, a conditional, a line range, a child list, and an indication of the testing status of the node;

executing, against the software artifact, a set of existing test cases;

collecting, responsive to the executing, log data, wherein the log data is generated from the executing of the set of existing test cases;

detecting, in the log data, a set of untested leaf nodes;

receiving, in response to the detecting a set of untested leaf nodes and from a user, a set of parameters specifying a subset within the set of untested leaf nodes, wherein the subset of the new test cases comprise new test cases which successfully tested one or more of the untested leaf nodes in the subset of untested leaf nodes specified by the parameters;

generating, for the set of untested leaf nodes, a set of new test cases, wherein each new test case in the set of new test cases is generated to test untested leaf nodes in the set of untested leaf nodes;

executing, against the software artifact, the set of new test cases;

determining, from the set of new test cases and based on the executing the set of new test cases, a subset of the new test cases, wherein the subset comprises new test cases which successfully tested one or more untested leaf nodes in the set of untested leaf nodes, and wherein the determining comprises:

identifying a set of particular test cases from the set of new test cases that cover adjacent neighbor nodes; and

adding, to the subset of new test cases, the set of particular test cases; and

adding, to the set of existing test cases, the subset of the new test cases.

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